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International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04Q 7/30

A1

(11) International Publication Number: WO 96/35302

(43) International Publication Date: 7 November 1996 (07.11.96)

(21) International Application Number: PCT/US96/05943

(22) International Filing Date: 29 April 1996 (29.04.96)

(30) Priority Data:
08/434,598 4 May 1995 (04.05.95) US

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(81) Designated States: AL, AM, AT, AU, AZ, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published

With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: CELLULAR BASE STATION WITH INTELLIGENT CALL ROUTING

(57) Abstract

A base station communicates with a plurality of mobile stations over a cellular network. In one embodiment, the base station includes a transceiver configured to receive inbound information from the mobile station and transmit outbound information to the mobile station. The transceiver equalizes and decodes the inbound information and encodes the outbound information. The transceiver is coupled to a data bus for communicating the inbound and outbound information with the other elements in the base station. The transceiver is also coupled to a control bus. A trunk module is coupled to the data bus and to a mobile services center. The trunk module communicates inbound and outbound information with the mobile services center. The trunk module is also coupled to the control bus. Finally, a central processor is coupled to the control bus to control the transceiver and the trunk module. A preferred protocol is Global Systems for Mobile Communication (GSM).

CELLULAR BASE STATION WITH INTELLIGENT CALL ROUTING

RELATED APPLICATIONS

The present application incorporates the following patent applications by reference:

CELLULAR PRIVATE BRANCH EXCHANGES, U.S. Ser. No. 08/435,709, filed on May 4, 1995, Attorney docket No. WAVEP001;

METHODS AND APPARATUSSES FOR AN INTELLIGENT SWITCH, U.S. Ser. No. 08/435,838 filed on May 4, 1995, Attorney docket No. WAVEP004;

SPREAD SPECTRUM COMMUNICATION NETWORK WITH ADAPTIVE FREQUENCY AGILITY, U.S. Ser. No. 08/434,597, filed on May 4, 1995, Attorney docket No. A-60820; and

SPREAD SPECTRUM COMMUNICATION NETWORK SIGNAL PROCESSOR, U.S. Ser. No. 08/434,554, filed on May 4, 1995, Attorney docket No. A-60910.

FIELD

The present invention relates to a cellular base station with intelligent call routing. In particular, the present invention is used in a cellular network to communicate with mobile stations and control the information routing to reduce network congestion and improve network performance.

BACKGROUND

Cellular communication networks typically employ base transceiver stations that communicate with mobile stations. When a mobile station (MS) initiates a call to the base transceiver station (BTS), it does so with an identification code. The BTS sends the identification code to a base station controller (BSC) and mobile switching center (MSC) for authentication. The MSC determines if the identification code matches one in a valid subscriber registry. Once

authenticated, the BTS is authorized to communicate with the MS and the network places the call.

Ordinarily, this procedure is efficient. For example, when a MS wishes to communicate with a person at home, via land line, the mobile transmission is routed through the base station, BSC, MSC, public switch telephone network (PSTN), and then via land line to the person at home.

However, when one MS wishes to communicate with another MS, the communication is still required to route through the MSC. This type of routing is not efficient because it reserves a portion of valuable BSC, MSC, and sometimes PSTN resources for the call. Moreover, when the base station employs a transcoder rate adapter (TRAU), a private branch exchange (PBX), or other subsystems, a portion of those resources are also reserved for the call.

Hence, one limitation of existing cellular communication networks is that the BTS and BSC must always communicate with the MSC in order to place a call from one MS to another. Moreover, this routing may require a rate adaptation even when the two MS are operating at the same rate.

Another limitation of existing cellular communication networks is that they employ dedicated hardware that lacks flexibility. For example, the BTS and BSC may be required to route calls to the MSC whether this routing is most efficient or not. As another example, these networks may impose rate adaptation on all communications to match a standard rate (e.g., 64Kbps), whether adaptation is necessary or not.

Still another limitation of existing cellular communication networks is that they lack flexibility to incorporate advanced features such as call routing in the BTS and BSC. These networks lack the ability to be scaled and modularized, and lack the flexibility to perform multiple tasks. Moreover, since existing communication networks use a great deal of dedicated hardware, a fault can cause data loss, or even cause the network to malfunction. When a BTS or BSC is broken, the network must operate in a reduced capacity, if it can operate at all.

SUMMARY

The present invention relates to a cellular base station with intelligent call routing. In particular, the present invention is used in a cellular network to communicate with mobile stations and control the information routing to reduce network congestion and improve network performance. Exemplary embodiments are provided for use with the Global Systems for Mobile Communication (GSM) protocol.

A base station communicates with a plurality of mobile stations over a cellular network. In one embodiment, the base station includes a transceiver configured to receive inbound information from the mobile station and transmit outbound information to the mobile station. The transceiver equalizes and decodes the inbound information and encodes the outbound information. The transceiver is coupled to a data bus for communicating the inbound and outbound information with the other elements in the base station. The transceiver is also coupled to a control bus. A trunk module is coupled to the data bus and to a mobile switching center. The trunk module communicates inbound and outbound information with the transceiver and the mobile switching center. The trunk module is also coupled to the control bus. Finally, a cellular central processor is coupled to the control bus to control the transceiver and the trunk module.

In another embodiment, the base station may include a plurality of transceivers, cellular central processors, and trunk modules. The base station architecture is modular and scalable. As a result, the base station can be modified to perform a variety of tasks and scaled to accommodate various performance requirements. For example, a low performance base station may have only one transceiver, one cellular central processor, and one trunk module. A high performance base station may have several transceivers, cellular central processors, and trunk modules.

Advantages of the present invention include modularity, scalability, distributed processing, improved performance, reduced network congestion, fault tolerance, and more efficient and cost-effective base stations.

BRIEF DESCRIPTION OF THE DRAWINGS

Additional advantages of the invention will become apparent upon reading the following detailed description and upon reference to the drawings, in which:

Figure 1 depicts a cellular network;

Figures 2A-D are flow charts showing steps performed to process inbound information and outbound information;

Figure 3 depicts a base transceiver station according to one embodiment of the invention;

Figure 4 depicts a radio frequency (RF) distribution module according to one embodiment of the invention;

Figure 5 depicts a transceiver (TRX) module according to one embodiment of the invention;

Figure 6 depicts a cellular central processor according to one embodiment of the invention;

Figure 7 depicts a trunk module according to one embodiment of the invention;

Figure 8 depicts a detailed schematic of a trunk module according to another embodiment of the invention;

Figures 9A-D depict a configuration for switching information at sub-64Kbps rate;

Figure 10 depicts a base transceiver station according to another embodiment of the invention;

Figure 11 depicts a base transceiver station according to another embodiment of the invention;

Figure 12 depicts a base transceiver station according to another embodiment of the invention;

Figure 13 is a table depicting various embodiments of a base station according to the invention;

Figures 14A-D are flow charts showing steps performed to process inbound information and outbound information; and

Figures 15A-D are flow charts showing steps performed to process inbound information and outbound information;

DETAILED DESCRIPTION

The present invention relates to a cellular base station having an intelligent routing control switch. In particular, the present invention is used in a cellular network to

communicate with mobile stations and control the information routing to reduce network congestion and improve network performance. Exemplary embodiments are provided for use with the Global Systems for Mobile Communication (GSM) protocol.

The exemplary embodiments are described herein with reference to specific configurations and protocols. Those skilled in the art will appreciate that various changes and modifications can be made to the exemplary embodiments while remaining within the scope of the present invention.

For purposes of this description, the term base station (BS) includes the structure and features present in any of the BTS, BSC, or MSC. The exemplary embodiments are capable of performing any of these functions depending on their individual configuration, as explained below. Further, the term information includes both RF signals and digital words that can represent voice, data, or both.

A first embodiment is described with reference to Figures 1 through 3. Figure 1 depicts a cellular network showing mobile stations (MS) 20 communicating with base transceiver stations (BTS) 40. When a MS initiates a call to BTS 40, it does so with an international mobile subscriber identification code (IMSI). BTS 40 sends the IMSI to a base station controller (BSC) 50 and mobile services center (MSC) 60 for authentication. MSC 60 determines if the IMSI matches one in a visitor location registry (VLR) 70. If the IMSI is not found in VLR 70, MSC 60 looks into a home location registry (HLR) 80 to try to match the IMSI. If the IMSI is not found in HLR 80, MSC 60 looks out through the public switched telephone network (PSTN) 90 to try to match the IMSI in other network HLRs. Once authenticated, BTS 40 is authorized to communicate with MS 20 and the network places the call.

Figures 2A-D show the procedures for BS 30 to communicate with MS 20. These flowcharts are indicative of a separate BTS 40, BSC 50, MSC 60 configuration, and show what processing steps are performed in what location. The Figure 2A flowchart shows inbound information processing beginning with step 102 where the information is received from the MS.

Step 104 involves framing a GSM TDMA word. In step 106, the information is equalized to compensate for multipath effects. Step 108 decodes the information. Step 110 de-interleaves the inbound information. Steps 112 and 114 are information transport steps over a trunk module (TM) which, for convenience is hereinafter described by way of example as an exemplary E1 trunk. Step 116 is a TRAU function that is performed only when required, as explained below. Steps 118 and 120 are information transport steps over an exemplary E1 trunk. Step 122 is a switching step that routes the inbound information to a correct destination. If the destination is at the BTS, the information can be routed back to the BTS as outbound information (goto Figure 2C step 152). However, if the inbound information is destined for PSTN 90, step 124 is performed to echo cancel the information. Then, step 126 sends the inbound information over an exemplary E1 trunk to an outbound destination.

The Figure 2B flowchart shows the inbound control signal processing. This represents the control information necessary to support voice and data communication with MS 20. Steps 102 through 110 are the same as those in the Figure 2A flowchart. Step 130 involves base station control functions including control of the base station radio and MS power and timing. Step 132 is an Abis function which is a protocol between the BTS and BSC. Steps 112 and 114 are information transport steps over an exemplary E1 trunk. Step 134 is an Abis function which is a protcol between the BTS and BSC. Step 136 is a radio resource management (RR) procedure. Step 138 is an A function which is a protocol between the BSC and MSC. Steps 118 and 120 are information transport steps over an exemplary E1 trunk. Step 140 is an A function which is a protcol between the BSC and MSC. Step 142 can represent a variety of management procedures including radio resource management (RR), mobility management (MM), call control (CC), supplemental services (SS), and short message service (SMS). Step 144 is SS7 protocol processing, which enables cooperative interworking between other elements of the GSM network and the PSTN. Step 126 sends the inbound signal

information over an exemplary E1 trunk to an outbound destination.

The Figure 2C flowchart shows outbound information processing. Step 150 receives the outbound information from an exemplary E1 trunk. Step 152 is a switching step that routes the outbound information to a correct destination. Steps 154 and 156 are information transport steps over an exemplary E1 trunk. Step 158 is a TRAU step. Steps 160 and 162 are information transport steps over an exemplary E1 trunk. Step 164 interleaves the outbound information. Step 166 encodes the outbound information. Steps 168 places the outbound information into TDMA frames. Step 170 transmits the outbound information to MS 20.

The Figure 2D flowchart shows the outbound signal path processing. Step 150 receives the outbound information from an exemplary E1 trunk. Step 172 is a SS7 protocol processing, which enables cooperative interworking between other elements of the GSM network and the PSTN. Step 174 can represent a variety of management procedures including radio resource management, mobility management, call control, supplemental services, and short message service. Step 176 is an A function which is a protocol between the MSC and BSC. Steps 154 and 156 are information transport steps over an exemplary E1 trunk. Step 178 is an A function which is a protcol between the MSC and BSC. Step 180 is a radio resource management procedure. Step 182 is an Abis function which is a protcol between the BSC and BTS. Steps 160 and 162 are information transport steps over an exemplary E1 trunk. Step 184 is an Abis function which is a protcol between the BSC and BTS. Step 186 involves base station control functions including control of the radio and MS power and timing. Step 164 interleaves the outbound information. Step 166 encodes the outbound information. Steps 168 places the outbound information into TDMA frames. Step 170 transmits the outbound information to MS 20.

Figure 3 depicts an embodiment of a base station that communicates with MSs 20a, 20b and performs the inbound information processing and outbound information processing.

A radio frequency (RF) distribution module 210 amplifies and distributes inbound information to each transceiver (TRX) 250a-c. Each TRX 250 receives the inbound information and transforms the RF information into GSM TDMA format information. TRX 250 then frames, equalizes, decodes, and deinterleaves the inbound information, corresponding to steps 104, 106, 108, and 110 of Figure 2A-B.

TRX 250 is controlled by a cellular central processor (CCPU) 300 via a control bus (VME). CCPU 300 schedules all information processing and keeps track of communication with MS 20. CCPU 300 also controls a trunk module (TM) 400 via the VME bus.

TRX 250 then sends the information to TM 400 via a data bus (TDM), which contains 16 8Mbps subbusses. Each TRX module 250a-c can receive on any subbus and is given a predetermined subbus on which to send information to TM 400. TM 400 is a sophisticated module that includes a time/space switch, explained below. CCPU 300 controls the operation of TM 400 and determines whether TM 400 should perform any rate adaptation, echo cancelling, or interface functions, corresponding to steps 116, 122, and 124.

The outbound information processing is similarly performed as follows. TM 400 performs, if required, the interface functions and rate adaptation, corresponding to step 158. TM 400 then sends the information to TRX 250 via TDM bus for interleaving, encoding, framing and RF transmission, corresponding to steps 164, 166, 168, and 170.

In particular, Figure 4 depicts RF distribution module 210. Antennae 212, 214 are coupled to diplexers 216, 218 respectively. Diplexers 216, 218 serve as filters that permit reception and transmission on the same antenna since the receive frequency is disjoint from the transmit frequency. Distribution circuits 220, 222 are used to provide fan out of received RF information. One of the circuit 220, 222 outputs are fed to a diversity switch 224. This switch 224 is controlled by downstream processing in order to select antenna 212, 214 with the best reception. In mixer 226, a 13MHz clock frequency is superimposed on the

received signal to synchronize downstream elements such as TRX 250.

Figure 5 depicts TRX 250. Filter 227 extracts the 13MHz clock for TRX 250 synchronization. A diversity control 228 is coupled to the RF distribution module 210 to control diversity switch 224. Diversity control 228 monitors the incoming received signal to detect signal degradation. If, for example, diversity control 228 detects sufficient signal degradation in antenna 212, it sends a signal to switch 224 in RF distribution module 210 to select antenna 214. The RF communication and reception aspect is discussed in detail in SPREAD SPECTRUM COMMUNICATION NETWORK WITH ADAPTIVE FREQUENCY AGILITY, U.S. Ser. No. 08/434,597, filed on May 4, 1995, Attorney docket No. A-60820.

Once the inbound information is received at TRX 250 and converted to a baseband frequency, a GSM baseband module 230 performs a GMSK procedure to obtain TDMA frame data. GSM baseband module 230 can perform both inbound demodulation resulting in in-phase and quadrature-phase information as well as outbound modulation resulting in a baseband frequency. A processor that works well for this purpose is the Analog Devices AD7002. Then MUX/DMUX 252 directs the inbound information to a plurality of processing paths to distribute the processing load. The signal processing aspect is discussed in detail in SPREAD SPECTRUM COMMUNICATION NETWORK SIGNAL PROCESSOR, U.S. Ser. No. 08/434,554, filed on May 4, 1995, Attorney docket No. A-60910. One example of demultiplexing that works well is to send all even TDMA time slots to a first DSP string 254, 256, and to send all odd TDMA time slots to a second DSP string 258, 260. However, MUX/DMUX 252 can distribute the information to any number of DSP strings. Once DSPs 256, 260 complete the inbound information processing, they send the information to the TDM bus.

For outbound information processing, DSPs 256, 260 receive outbound information from the TDM bus. The information is divided among a plurality of processing strings. One example that works well is to send all even

TDMA time slots to a first DSP string 256, 254, and to send all odd TDMA time slots to a second DSP string 260, 258. The processing is performed in parallel and the resulting outbound information is presented to MUX/DMUX 252, which multiplexes the time slots to form TDMA frames, sends them to GSM baseband module 230 and then to RF distribution module 210 for transmission.

While TRX 250 is described for TDMA, any type of modulation, multiple access, or other information coding techniques are possible. For example, GSM baseband converter 230 can be replaced or supplemented with a converter for performing CDMA, and DSP 254, 256, 258, 260 program memory can be replaced or supplemented with procedures to perform CDMA. Thus, the modular architecture is capable of performing as any type of base station for a variety of different types of networks.

A Real Time Processor (RTP) 262 provisions and controls DSPs 254, 256, 258, 260 in order to schedule information processing. RTP 262 also performs power control and measurement preprocessing and link access protocols (LAPDm) for information error detection and correction. Moreover, RTP 262 keeps track of inbound information and outbound information to further enhance TRX 250 efficiency and permit the communication of inbound information and outbound information over the TDM bus.

RTP 262 communicates control information over the VME bus with CCPU 300, and receives instructions from CCPU 300 regarding operating parameters and processing requirements. Included in this control information is base station radio and MS power and timing information collected by TRX 250 as well as other packetized information from the MS. Because RTP 262 is incorporated in TRX 250, and since RTP 262 is a dedicated processor, the TRX processing performance is predicable and guaranteed.

RTP 262 is also very useful in microcell configurations where a TRX service area is small and the signal degrades rapidly. In microcell configurations, the signal strength rapidly attenuates with respect to distance. As a result,

microcell configurations may require very frequent statistics gathering and error checking in order to adequately manage the MSs. A conventional radio architecture lacks the processing power to handle frequent statistics gathering with a number of MSs in a microcell configuration and may drop the MS, which may have already left the service. The invention overcomes the processing hurdle by incorporating RTP 262 in TRX 250 to provide processing that supports microcell configurations and frequent statistics gathering.

RTP 262 serves the goal to distribute processing power and delegate processing tasks to where the tasks can be most efficiently performed. In a single TRX configuration, RTP 262 can even perform all the necessary functions so that a CCPU 300 is not required. Also, as described below, when the number of TRX cards increases, the processing power scales proportionally. By performing the processing tasks in the TRX, the control traffic is minimized between the TRX and CPU, and the CPU load is not significantly increased with additional TRXs.

Figure 6 depicts CCPU 300. A VME interface 302 is coupled to the VME bus and buffers all communication therewith. A redundancy control 304 is coupled to interface 302 to monitor interface 302 and to take over if necessary. Processor 306 is coupled to interface 302 to communicate over the VME bus. Processor 306 receives the packetized information from a MS when a call is placed. Processor 306 controls the signalling path of the call and configures TM 400 to accommodate the call switching. Additionally, processor 306 performs many of the housekeeping and scheduling functions required in the BS such as maintaining a record of active MSs, MS information rates, call connection information, and other information. Moreover, relating back to Figures 2B and 2D, processor 306 can provide BCF, RR, MM, SS, CC, or SMS functions if desired (steps 136, 142, 174, 180). Clock adjust 308 receives a clock signal and correlates the signal with other tracking information, such as data transfer clocks, to conform the clock to a uniform standard. CCPU 300 also has a variety of ports for modules

such as DRAM 310, flash memory 312, a spare port 314 for IDE, SCSI, or RS232, and ethernet 316.

Some configurations described below have several CCPUs. Benefits of additional CCPUs include redundancy, flexibility and increased central processing power. When the base station is coupled to several other network elements, central processing power is useful to coordinate inbound and outbound information, and to control TM 400 switching as described below.

Figures 7 and 8 depict TM 400. At the heart of TM 400 is a time/space switch 402, which is coupled to both the TDM bus for data and the VME bus for control. Time/space switch 402 is capable of routing information between the TDM bus, processor 404, interface framers 410, and DSPs 420a-f. Time/space switch 402 is described herein according to its communication data rates and switch capabilities. Any device of performing these functions can be used in the present invention, such as the 3C Ltd. C3280 processor.

Time/space switch 402 has many ports as shown in Figure 8. A PCM input port is coupled to all 16 TDM subbusses, which can each transfer 8Mbps. In essence, time/space switch 402 can communicate with up to 16 modules such as TRXs, other TMs, or any other type modules attached to the TDM bus. A larger number is possible if time/space switch 402 is configured to have even more ports and the TDM bus is configured to have even more subbusses.

Time/space switch 402 supports many of the switching functions described in CELLULAR PRIVATE BRANCH EXCHANGES, U.S. Ser. No. 08/435,709, filed on May 4, 1995, Attorney docket No. WAVEP001, and METHODS AND APPARATUSSES FOR AN INTELLIGENT SWITCH, U.S. Ser. No. 08/435,838, filed on May 4, 1995, Attorney docket No. WAVEP004. Moreover, when the base station is configured to perform switching functions, the base station can perform functions of a cellular PBX, a local loop, or other similar functions.

Processor 404 is coupled to time/space switch 402 via 8Mbps CPU360Y and CPU360Z input ports, and further coupled to 8Mbps PathY and PathZ output ports, as shown. Processor 404

is also coupled to VME bus, as shown in Figure 7. Processor 404 is provided to perform protocol processing. Possible protocols include Abis, A, SS#7, and ISDN. This processing enables cooperative interworking between other elements of the GSM network and the PSTN. Moreover, processor 404 provides distributed processing that is dedicated to the TM 400 and becomes scaled as the number of TMs increases. Processor 404 also serves as a protocol engine for TM 400 and helps reduce latency and improve performance for handling SS#7 signalling. If protocol processing is not required, and a CCPU 300 is present in the configuration, then processor 404 may be omitted since CCPU 300 includes processor 306 for performing general functions.

Framers 410, 412 are coupled to time/space switch 402 via 2Mbps framer ports TxA and TxB. The 2Mbps is an E1 interface rate, but can be modified for any interface rate. Framers 410, 412 are configured to communicate with other network elements such as a BTS, BSC, MSC, PBX, PSTN, or others. Since the base station can be configured to perform the functions of a BTS, BSC, or MSC, the type of interface may be changed to accommodate the particular required interface function. For example, framers 410, 412 shown in Figure 7 can interface with an E1 at 2Mbps, a T1 at 1.544Mbps, DS0 at 64Kbps, or other digital interface.

DSPs 420a-f are coupled to time/space switch via 8Mbps PathY and pathZ output ports. DSPs 420a-f can perform a variety of functions including transcode rate adaptation, echo cancelling, or other special functions such as those described below. Once DSPs 420a-f complete their respective functions, the information is then delivered back to time/space switch 402 via pathY and pathZ input ports.

As explained above with reference to Figure 2A, the required information processing may sometimes include echo cancelling (step 124), transcode rate adaptation TRAU (step 116), or other internetwork functions (IWF). Time/space switch 402 receives control signals from CCPU 300 over the VME bus, instructing time/space switch 402 what to switch or connect.

When echo cancelling, rate adaptation, or scme other function is required, time/space switch 402 routes the information to a DSP 420 to perform the processing. As shown, there are 6 DSPs 420a-f, however, there may be from zero to any number as required for the processing. Further, the DSPs 420a-f may each have 2 or 4 processor engines such as AT&T DSP1611 or TI TMS320C52 to perform the required processing function.

With regard to the TRAU function, the GSM MS communicates compressed voice at 16Kbps, while the PSTN DS0 interface is 64Kbps. A DSP 420 modifies the compression to accommodate this rate change. The DSP 420 can also accommodate a rate change between any rates such as 8Kbps, 16Kbps and 64Kbps.

As mentioned above, information traffic switching at rates below 64Kbps is a feature of the invention. Two aspects of the sub-64Kbps information switching are described. First, a communication is described that enables sub-64Kbps data streams to be assembled into a standard DS0 64Kbps data stream. To accomplish this aspect, the DSPs 420a-f are employed to assemble sub-64Kbps data streams into DS0 data streams to send to other network elements, and to disassemble DS0 data streams from other network elements. For example, Figure 9A shows an 8-bit 64Kbps DS0 data stream 502 containing 4 16Kbps data streams (W1, W2, W3, W4) and an 8-bit 64Kbps DS0 data stream 504 containing 8 8Kbps data streams (W1, W2, W3, W4, W5, W6, W7, W8). This permits either 4 16Kbps calls or 8 8Kbps calls to be communicated in a single DS0 data stream, where conventionally only one call is supported. Moreover, the DS0 data stream can contain a lesser number by padding the data streams with predetermined bits.

Figure 9B depicts how DSPs 420a-f can be configured to perform the assembly and disassembly required to read and write the sub-64Kbps data streams into 64Kbps data streams. Each DSP 420 that is instructed to perform the communication has its memory configured with 4 buffers and a map, where the first 4 (M1, M2, M3, M4) are buffers for storing the data

streams and number 5 (M5) is for storing the memory map to direct the DSP function buffer memory mapping. Figure 9B shows how buffer M1 is mapped to buffer M3 and buffer M2 is mapped to buffer M4, although any mapping can be programmed.

Figure 9C is a flowchart describing the procedure for mapping TDM information into a DS0 64Kbps data stream. Step 520 is where time/space switch 402 receives time slots information from the TDM bus. Step 522 switches desired time slots to selected DSP 420a-f via PcmOut4-7 and PathZ or PathY. In step 524, CCPU 300 sends a map via the VME bus to selected DSP 420a-f that programs the mapping function into M5. Step 526 shifts a portion of the time slot information into buffer M1 while information is being shifted out from buffer M4 via PathY or PathZ to time/space switch 402. Step 528 performs the mapping from buffer M1 to M3. Step 530 shifts a portion of the time slot information into buffer M2 while information is being shifted out from buffer M3 via PathY or PathZ to time/space switch 402. Step 532 performs the mapping from buffer M2 to M4. Step 534 determines whether the DSP 420 should continue. Under normal circumstances, DSP 420 would continuously process information and the loop would continue. However, if the DSP is instructed to end, step 534 sends the processing to step 536 where the processing ends. Thereafter, DSP 420 is free to perform other processing.

Second, to comply with GSM, speech is sampled by MS 20 at 64Kbps and compressed to 13.2Kbps data streams using standard vocoder algorithms. The information is then sent to BTS 40 via RF communication. Each inbound 13.2Kbps data stream is received by TRX 250 and typically packed into a 16Kbps data stream and routed within BTS 40. In conventional equipment, these 16Kbps data streams are decompressed to 64Kbps and transferred to an MSC where standard 64Kbps switching is performed. However, the present invention is capable of intelligently routing calls at 8Kbps, 16Kbps, or other rates, thus avoiding unnecessary rate conversions.

This second aspect is apparent when a call is made from a first MS 20a to a second MS 20b within the base station

service area. Time/space switch 402 may simply route the inbound information from the first MS 20a back out onto the TDM bus as outbound information for the second MS 20b. This type of switching is explained below with reference to Figures 14A-D and 15A-D. Moreover, this type of switching is further explained in CELLULAR PRIVATE BRANCH EXCHANGES, U.S. Ser. No. 08/435,709, filed on May 4, 1995, Attorney docket No. WAVEP001, and METHODS AND APPARATUSSES FOR AN INTELLIGENT SWITCH, U.S. Ser. No. 08/435,838, filed on May 4, 1995, Attorney docket No. WAVEP004.

The call routing function can also be performed in a variety of other ways depending on the mobile station communication with a base station. For example, if a first MS 20a and a second MS 20b are communicating with a single TRX 250a, and within a single DSP string 254, 256, the DSP string can receive the inbound data from first MS 20a, and then send it as outbound information to second MS 20b. Since the inbound and outbound information is at 13.2Kbps, and is routed inbound and outbound within a single DSP string, it does not need to be packed into a 16Kbps data stream. As another example, if a first MS 20a and a second MS 20b are communicating with a single TRX 250a, but with different DSP strings, TRX 250a may receive the inbound data from first MS 20a in one DSP string, and then send it as outbound information to another DSP string and then to second MS 20b. Since the inbound and outbound information are processed by different DSP strings, the information is packed into a 16Kbps data stream for communication between the DSP strings. Moreover, in one case, the first DSP string communicates the information to the second DSP string over the TDM bus. As still another example, if a first MS 20a is communicating with a first TRX 250a and a second MS 20c is communicating with a second TRX 250b, first TRX 250a may receive the inbound information and send it via the TDM bus to second TRX 250b, which treats it as outbound information to second MS 20c. Since the inbound and outbound information are processed by different TRXs, the information is packed into a 16Kbps data stream for communication between TRXs. Note that

these examples do not send the information to TM 400. Note also that these examples do not decompress the information to 64Kbps.

Figure 10 depicts how the modular and scalable architecture of the invention is implemented with a TDM bus and a VME bus. RF distribution module 210 is coupled to TRX 250. TRX 250 is coupled to both the TDM bus and the VME bus. In particular, DSPs 256, 260 are coupled to the TDM bus and RTP 262 is coupled to the VME bus. CCPU 300 is coupled to the VME bus. A clock module 307 is coupled to the TDM bus and generates the reference clock which allows the subsystems to operate in a synchronized fashion. TM 400 is coupled to both the TDM bus and the VME bus. Figure 10 depicts a one-TRX BTS configuration, which is also depicted in Figure 11.

Figure 11 depicts a commercial product that encloses the various base station components into a chassis. The chassis can operate as a stand alone unit, or can be mounted to an equipment rack for deployment in the field. Moreover, any card can be placed in any slot. It is possible, by removing all TRXs, to build BSC or MSC configurations using just TM and CCPU cards.

Since the architecture is fully scalable, Figure 12 depicts a base station having 6 TRXs, 2 CCPUs, and 3 TMs. Any base station configuration and function can be accommodated by selecting processing elements for deployment. For example, Figure 13 shows various possible functions, such as BTS, BSC, combined BTS/BSC, MSC, combined BSC/MSC, and combined BTS/BSC/MSC, that can be achieved with the invention. A configuration having a single TRX and single TM is possible when the CCPU functions are incorporated in the TRX RTP 262 and TM processor 404.

Figures 14A-D show the various functional division of inbound information processing and outbound information processing for a combined BTS/BSC and MSC. Those steps common to Figures 2A-D have common numbers. Once the inbound information is de-interleaved (step 110), it is sent to time/space switch 402 (step 111). The time/space switch 402 can then route the inbound information to one of three

places: to the TRAU (step 116), to an E1 (step 118), or back to the TDM bus as outbound information (goto Figure 14C step 163). If the switch step 111 routes the information to the E1 (step 118), the inbound information is sent to the MSC. Step 120 receives the information at the MSC and switch step 122 can then route the inbound information to one of four places: to the TRAU (step 123), to an echo canceler (step 124), to an E1 (step 126), or back to the BTS/BSC as outbound information (goto Figure 14C step 152).

The Figure 14B flowchart shows the inbound control signal processing. Note the Faux Abis step 133. This step is performed to retain the interface between steps 130 and 136 where the information transport steps 112, 114 over an exemplary E1 trunk are removed.

With regard to outbound information, step 150 receives information from a foreign network via an E1. The MSC in this case only receives the information from the foreign network when the destination MS is communicating with a TRX under its control. A switch step 152 can then route the information to a TRAU (step 153) or to an E1 (step 160). The BTS/BSC receives the information on an E1 (step 162) and a switch step 163 can then route the information to a TRAU (step 158) or to a TRX that interleaves (step 164), encodes (step 166), and frames (step 168) the information and sends it to the destination MS via step 170. Note that both switch steps 152 and 163 can be initiated from Figure 14A steps 122 and 111 respectively.

The Figure 14D flowchart shows the outbound control signal processing. Note the Faux Abis step 183. This step is performed to retain the interface between steps 180 and 186 where the information transport steps 160, 162 over an exemplary E1 trunk are removed.

Figures 15A-D show the various functional division of inbound information processing and outbound information processing for a combined BTS/BSC/MSC. Those steps common to Figures 2A-D have common numbers. Once the inbound information is de-interleaved (step 110), it is sent to time/space switch 402 (step 111). The time/space switch 402

can then route the inbound information to one of four places: to a TRAU (step 116), to an echo canceler (step 124), to an E1 (step 126), or back to the TDM bus as outbound information (goto Figure 14C step 152). If the switch step 111 routes the information to the E1 (step 126), the inbound information is sent to a foreign network.

The Figure 15B flowchart shows the inbound control signal processing. Note the Faux A step 139. This step is performed to retain the interface between steps 136 and 142 where the information transport steps 118, 120 over an exemplary E1 trunk are removed.

With regard to outbound information, step 150 receives information from a foreign network via an E1. The BTS/BSC/MSC in this case only receives the information from the foreign network when the destination MS is communicating with a TRX under its control. A switch step 152 can then route the information to a TRAU (step 158) or to a TRX that interleaves (step 164), encodes (step 166), and frames (step 168) the information and sends it to the destination MS via step 170. Note that switch step 152 can be initiated from Figure 15A step 111.

The Figure 15D flowchart shows the outbound control signal processing. Note the Faux A step 177. This step is performed to retain the interface between steps 174 and 180 where the information transport steps 154, 156 over an exemplary E1 trunk are removed.

An important feature of the scalable architecture is that when TM cards are added, the switching ability of the base station increases. For example, by configuring a base station with 3 TM modules, as shown in Figure 12, the base station capacity is increased to 6 E1 output ports. This configuration provides both greater communication capacity to a MSC, as well as greater information switch capacity within the base station itself, such as between TRX cards.

Advantages of the present invention include modularity, scalability, distributed processing, improved performance, reduced network congestion, fault tolerance, and more efficient and cost-effective base stations.

As used herein, when a first element and a second element are coupled, they are related to one another, but need not have a direct path to one another. For example, an antenna element may be coupled to a processing element via a receiver. However, when a first element and second element are connected, they are required to have a direct path to one another.

ALTERNATIVE EMBODIMENTS

Having disclosed exemplary embodiments and the best mode, modifications and variations may be made to the disclosed embodiments while remaining within the scope of the present invention as defined by the following claims.

What is claimed is:

1. A base station for communicating with a mobile station, said base station comprising:

a transceiver configured to receive inbound information from the mobile station and transmit outbound information to the mobile station;

a signal processor coupled to said transceiver and to a data bus, said signal processor configured to equalize and decode said inbound information and to transmit said inbound information to said data bus, and configured to receive said outbound information from said data bus and encode said outbound information;

a trx processor coupled to said signal processor, said trx processor configured to control said signal processor; and

a trunk module having an interface processor coupled to said data bus and configured to receive said inbound information from said data bus and transmit said inbound information to a foreign network, and configured to receive said outbound information from a foreign network and transmit said outbound information to said data bus;

2. The base station of claim 1, wherein:

said trunk module further includes a time/space switch coupled to said data bus, a plurality of signal processors coupled to said time/space switch, and an interface framer coupled to said time/space switch.

3. The base station of claim 1, further comprising:

a control bus coupled to said trx processor and said trunk module; and

a central processor coupled to said control bus and configured to control said trx processor and said trunk module.

4. The base station of claim 3, wherein:

said trunk module further includes a time/space switch

coupled to said data bus, a plurality of signal processors coupled to said time/space switch, and an interface framer coupled to said time/space switch.

5. A base station for communicating with a mobile station comprising:

a trunk module having an interface processor coupled to a data bus and configured to receive inbound information from said data bus and transmit said inbound information to a foreign network, and configured to receive outbound information from a foreign network and transmit said outbound information to said data bus.

6. The base station of claim 5, wherein:

said trunk module further includes a time/space switch coupled to said data bus, a plurality of signal processors coupled to said time/space switch, and an interface framer coupled to said time/space switch.

7. The base station of claim 6, further comprising:

a control bus coupled to said trunk module; and

a central processor coupled to said control bus and configured to control said trunk module.

8. The base station of claim 6 further comprising:

a trx module including:

a transceiver configured to receive inbound information from the mobile station and transmit outbound information to the mobile station;

a signal processor coupled to said transceiver and to a data bus, said signal processor configured to equalize and decode said inbound information and to transmit said inbound information to said data bus, and configured to receive said outbound information from said data bus and encode said outbound information; and

a trx processor coupled to said signal processor, said trx processor configured to control said signal processor.

9. The base station of claim 8, further comprising:
a control bus coupled to said trx processor and said trunk module; and
a central processor coupled to said control bus and configured to control said trx module and said trunk module.

10. The base station of claim 9, further comprising:
a second trunk module having a second interface processor coupled to said data bus and configured to receive inbound information from said data bus and transmit said inbound information to a foreign network, and configured to receive outbound information from a foreign network and transmit said outbound information to said data bus.

11. The base station of claim 7, further comprising:
a plurality of trx modules each including:
a transceiver configured to receive inbound information from the mobile station and transmit outbound information to the mobile station;
a signal processor coupled to said transceiver and to a data bus, said signal processor configured to equalize and decode said inbound information and to transmit said inbound information to said data bus, and configured to receive said outbound information from said data bus and encode said outbound information; and
a trx processor coupled to said signal processor, said trx processor configured to control said signal processor.

12. The base station of claim 11, further comprising:
a control bus coupled to said trx processor and said trunk module; and
a central processor coupled to said control bus and configured to control said trx modules and said trunk module.

13. The base station of claim 12, further comprising:
a second trunk module having a second interface processor coupled to said data bus and configured to receive

inbound information from said data bus and transmit said inbound information to a foreign network, and configured to receive outbound information from a foreign network and transmit said outbound information to said data bus.

14. The base station of claim 11, further comprising:
a control bus coupled to said trunk module; and
a plurality of central processors coupled to said control bus and configured to control said trx modules and said trunk modules.

15. A method of communicating with a mobile station, using a base station comprising a trx module including a transceiver, a signal processor and a trx processor, said method comprising the steps of:
receiving inbound RF information from the mobile station in the transceiver;
converting said inbound RF information to inbound digital information;
processing the inbound digital information in the signal processor; and
controlling said processing step in the trx processor.

16. The method of claim 16, further comprising the steps of:
converting the inbound digital information to outbound digital information in the signal processor;
converting said outbound digital information to outbound RF information;
transmitting said RF information to the mobile station in the transceiver.

17. The method of claim 15, further comprising the steps of:
converting the inbound digital information to outbound digital information in the trx processor;
converting the outbound digital information to outbound RF information;
transmitting said RF information to the mobile station in the transceiver.

18. The method of claim 15 for further communicating with a second mobile station, wherein said base station further comprises a data bus and a second trx module, said method further comprising the steps of:

communicating the inbound digital information from the trx module to the data bus; and

receiving the inbound digital information from the trx module in the second trx module; and

converting the inbound digital information to outbound digital information in the second trx module;

converting the outbound digital information to outbound RF information;

transmitting the RF information to the second mobile station.

19. The method of claim 15 for further communicating with a second mobile station, wherein said base station further comprises a data bus and a trunk module, said method further comprising the steps of:

communicating the inbound digital information from the trx module to the data bus;

receiving the inbound digital information from the trx module in the trunk module;

converting the inbound digital information to outbound digital information in the trunk module;

communicating the outbound digital information to the data bus;

converting said outbound digital information to outbound RF information;

transmitting said RF information to the second mobile station.

20. The method of claim 19, further comprising the step of:

performing one of an assembly and a disassembly of a first data stream of one of said inbound digital information and said outbound digital information to generate a second data stream of one of said inbound digital information and said outbound digital information.

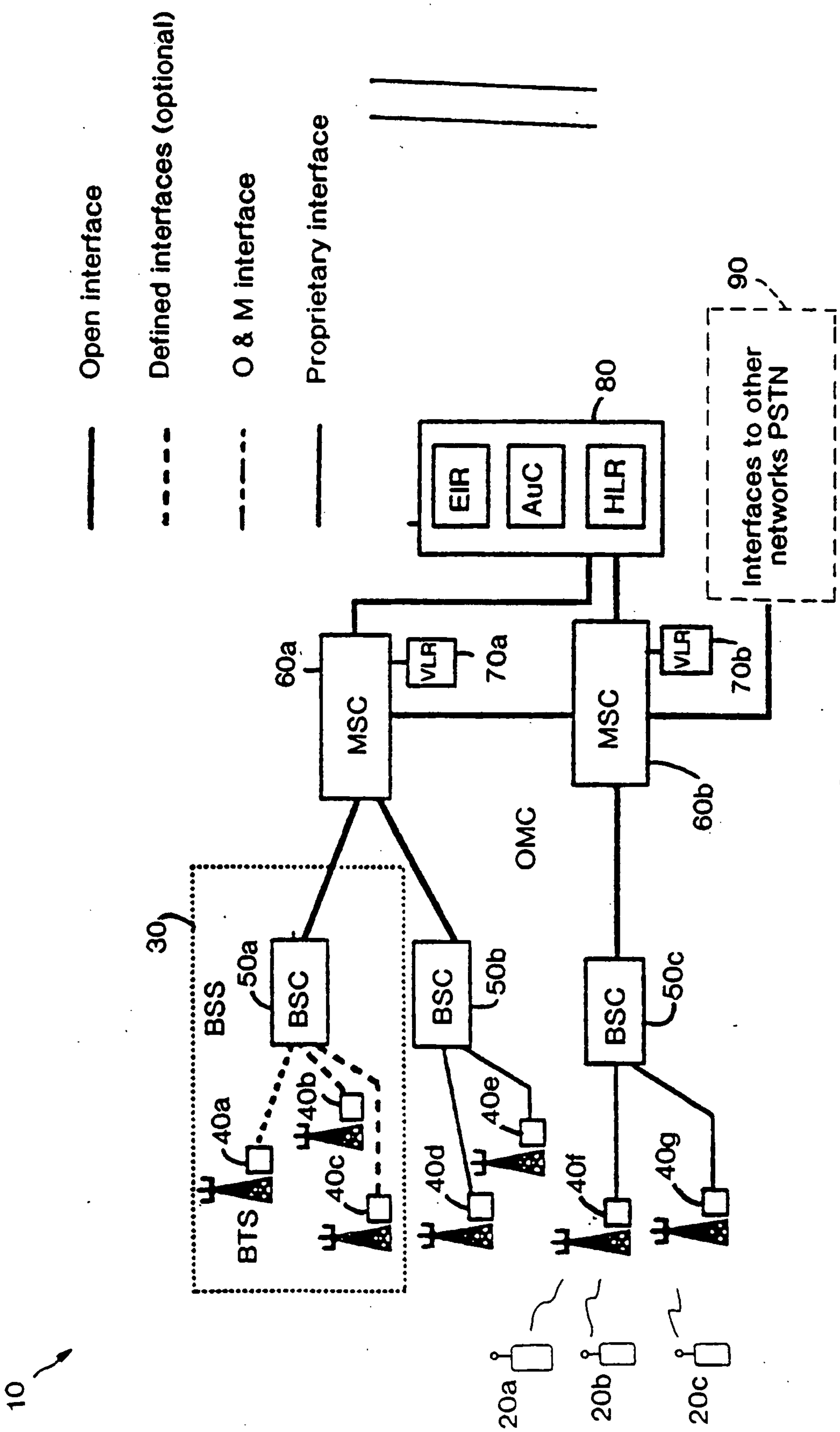

Open interface
Defined interfaces (optional)
O & M interface
Proprietary interface
10
20a
20b
20c
BTS
BSS
30
40a
40b
40c
40d
40e
40f
40g
BSC
50a
BSC
50b
BSC
50c
OMC
MSC
60a
MSC
60b
VLR
70a
VLR
70b
EIR
AuC
HLR
80
Interfaces to other networks PSTN
90

FIG. 1

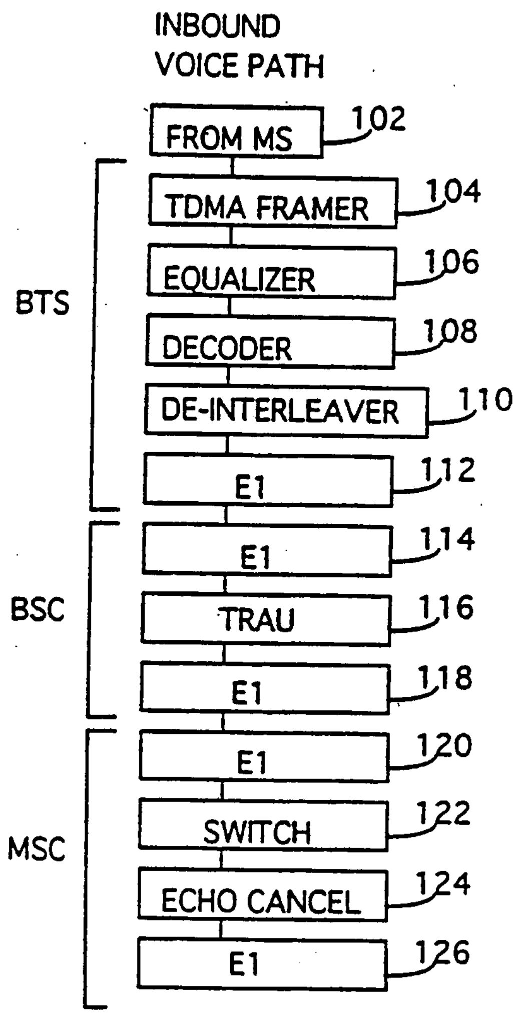

INBOUND
VOICE PATH
FROM MS
102
BTS
TDMA FRAMER
104
EQUALIZER
106
DECODER
108
DE-INTERLEAVER
110
E1
112
BSC
E1
114
TRAU
116
E1
118
MSC
E1
120
SWITCH
122
ECHO CANCEL
124
E1
126

FIG. 2A

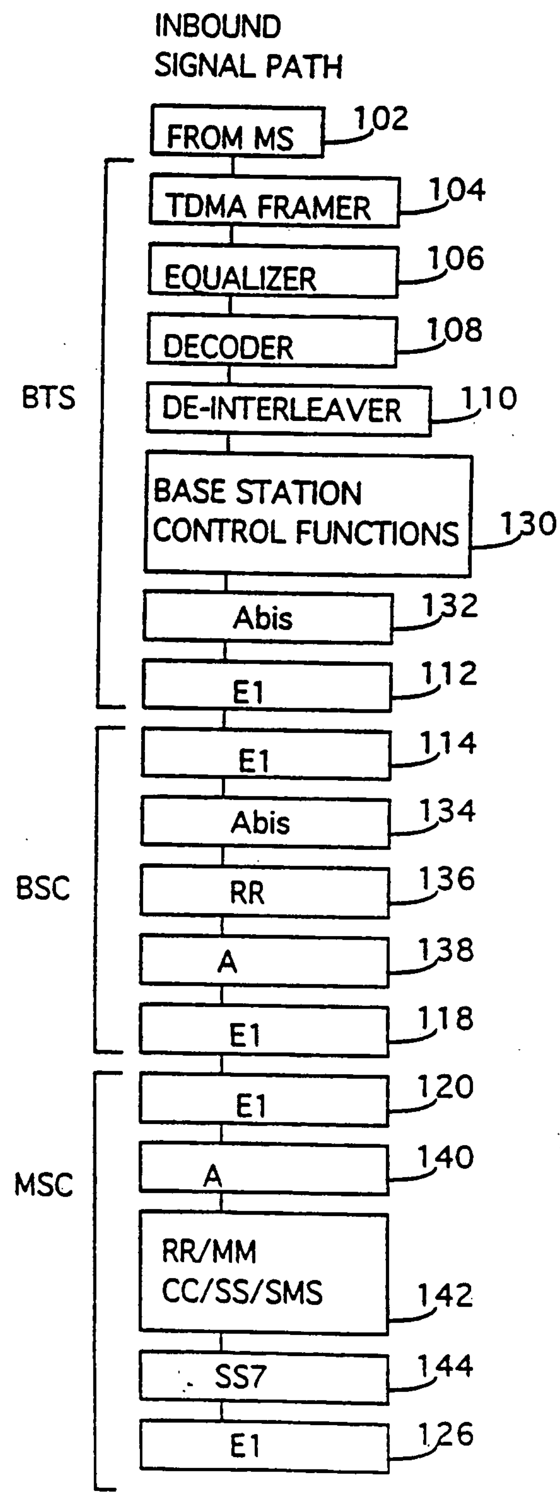

INBOUND
SIGNAL PATH
FROM MS
102
BTS
TDMA FRAMER
104
EQUALIZER
106
DECODER
108
DE-INTERLEAVER
110
BASE STATION
CONTROL FUNCTIONS
130
Abis
132
E1
112
BSC
E1
114
Abis
134
RR
136
A
138
E1
118
MSC
E1
120
A
140
RR/MM
CC/SS/SMS
142
SS7
144
E1
126

FIG. 2B

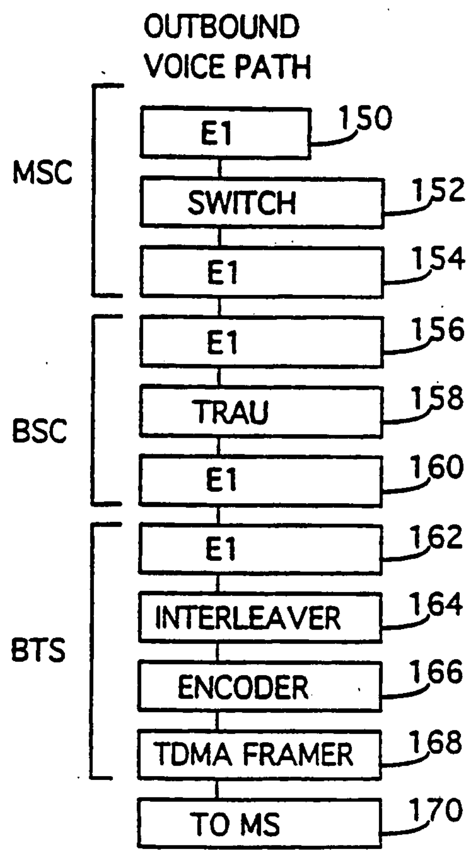

OUTBOUND
VOICE PATH
MSC
E1
150
SWITCH
152
E1
154
BSC
E1
156
TRAU
158
E1
160
BTS
E1
162
INTERLEAVER
164
ENCODER
166
TDMA FRAMER
168
TO MS
170

FIG. 2C

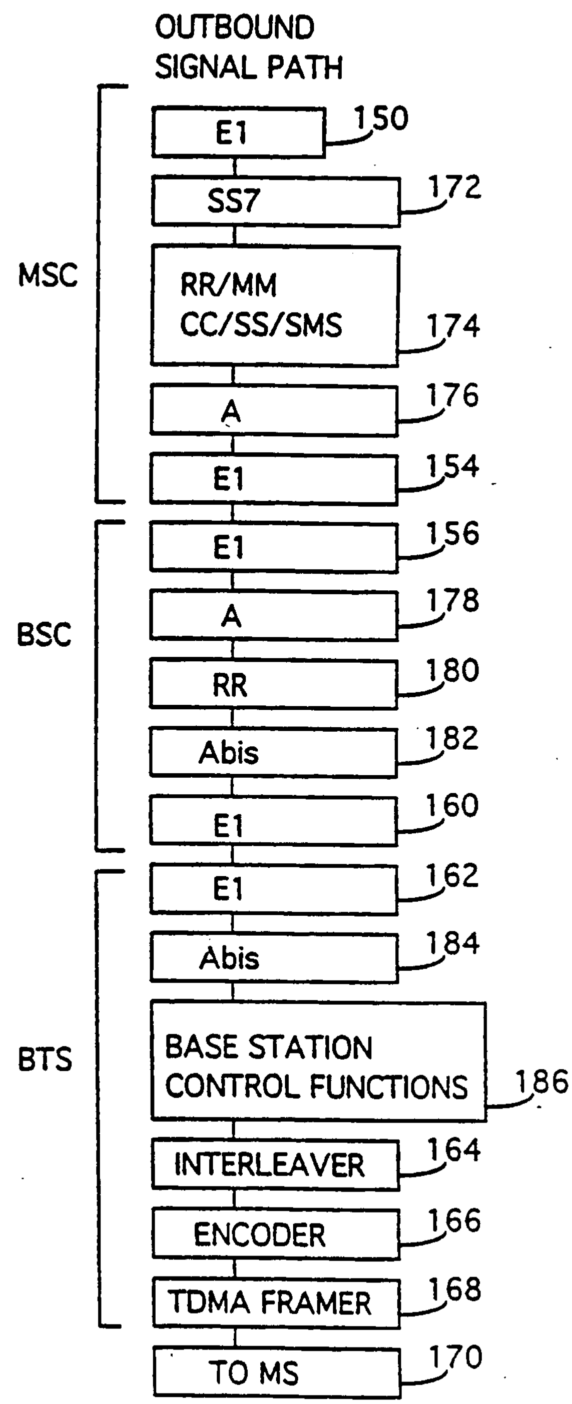

OUTBOUND
SIGNAL PATH
MSC
E1
150
SS7
172
RR/MM
CC/SS/SMS
174
A
176
E1
154
BSC
E1
156
A
178
RR
180
Abis
182
E1
160
BTS
E1
162
Abis
184
BASE STATION
CONTROL FUNCTIONS
186
INTERLEAVER
164
ENCODER
166
TDMA FRAMER
168
TO MS
170

FIG. 2D

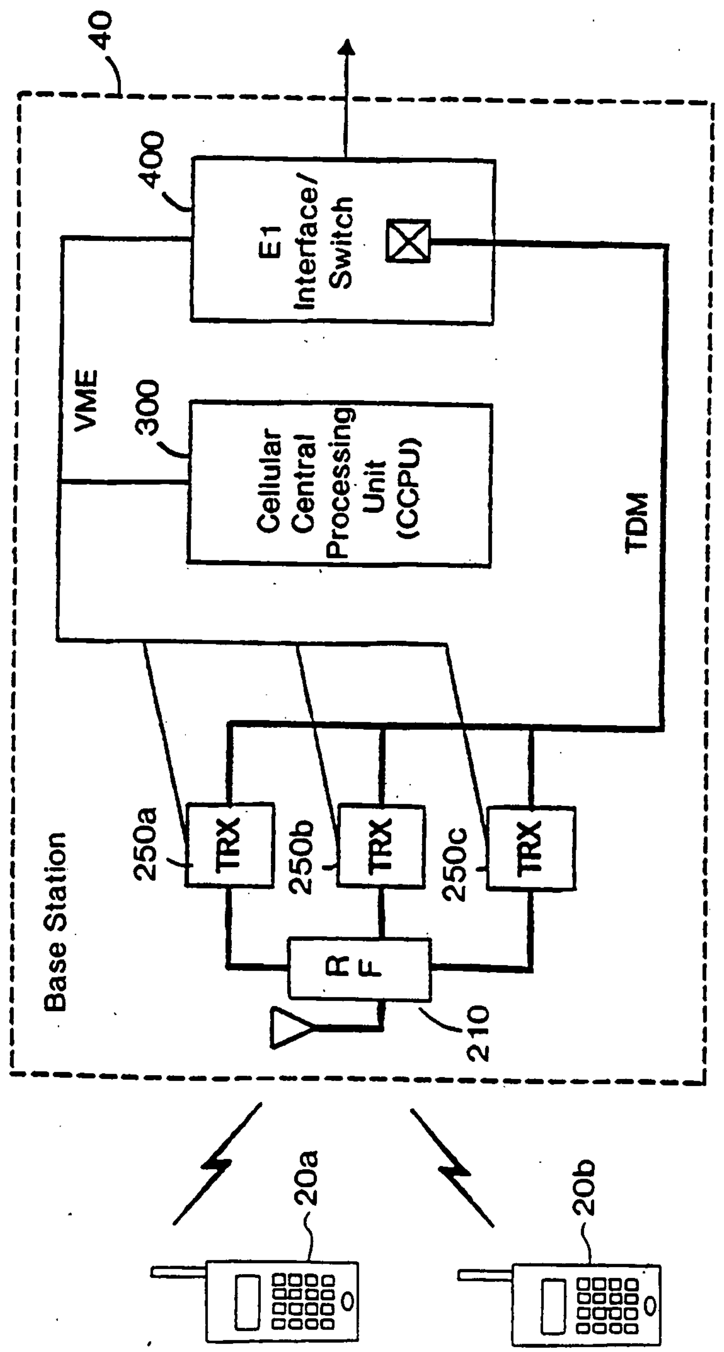

40
400
E1 Interface/ Switch
VME
300
Cellular Central Processing Unit (CCPU)
TDM
Base Station
250a
TRX
250b
TRX
250c
TRX
R F
210
20a
20b

FIG. 3

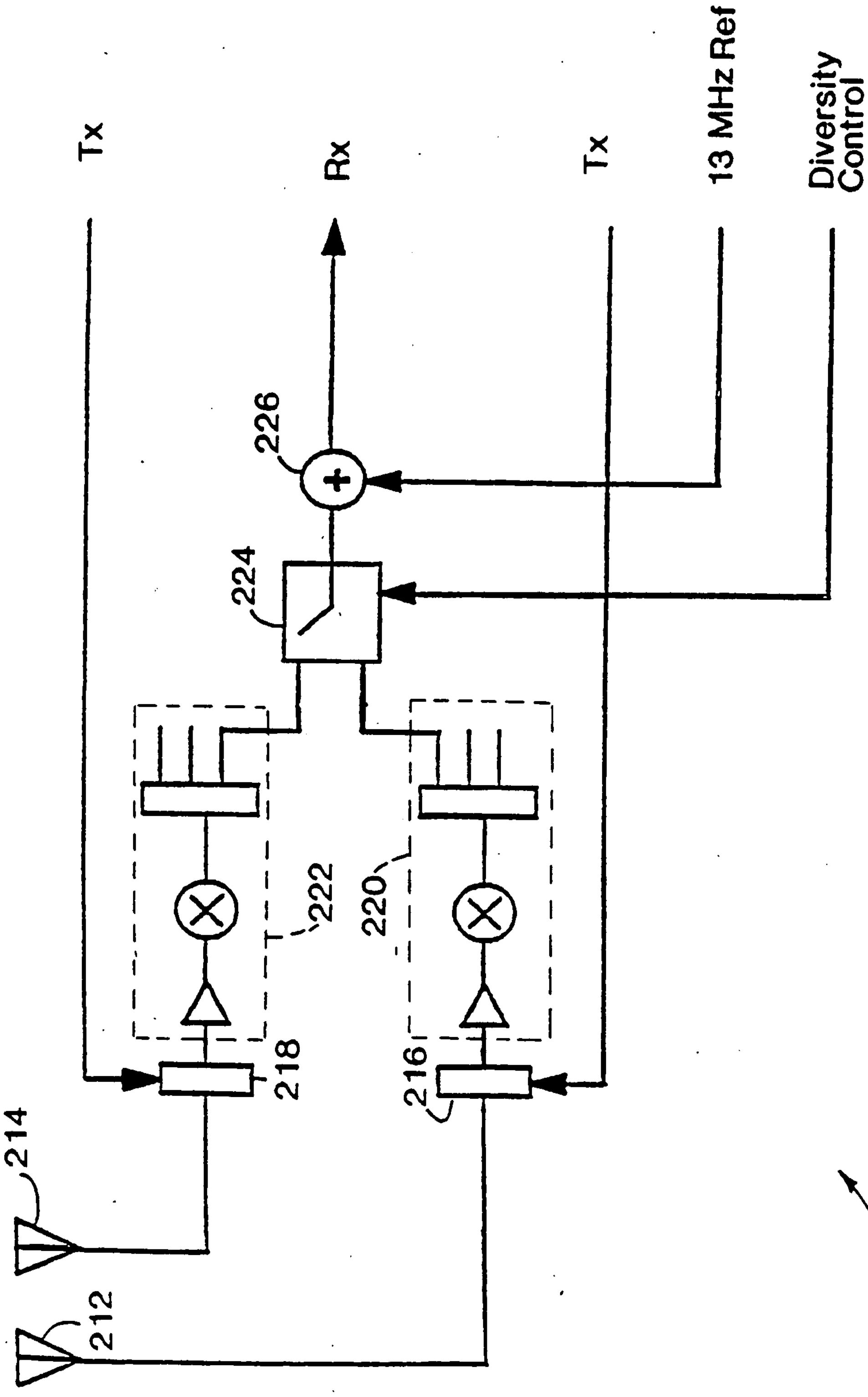

Tx
Rx
Tx
13 MHz Ref
Diversity Control
226
224
222
220
218
216
214
212
210

FIG. 4

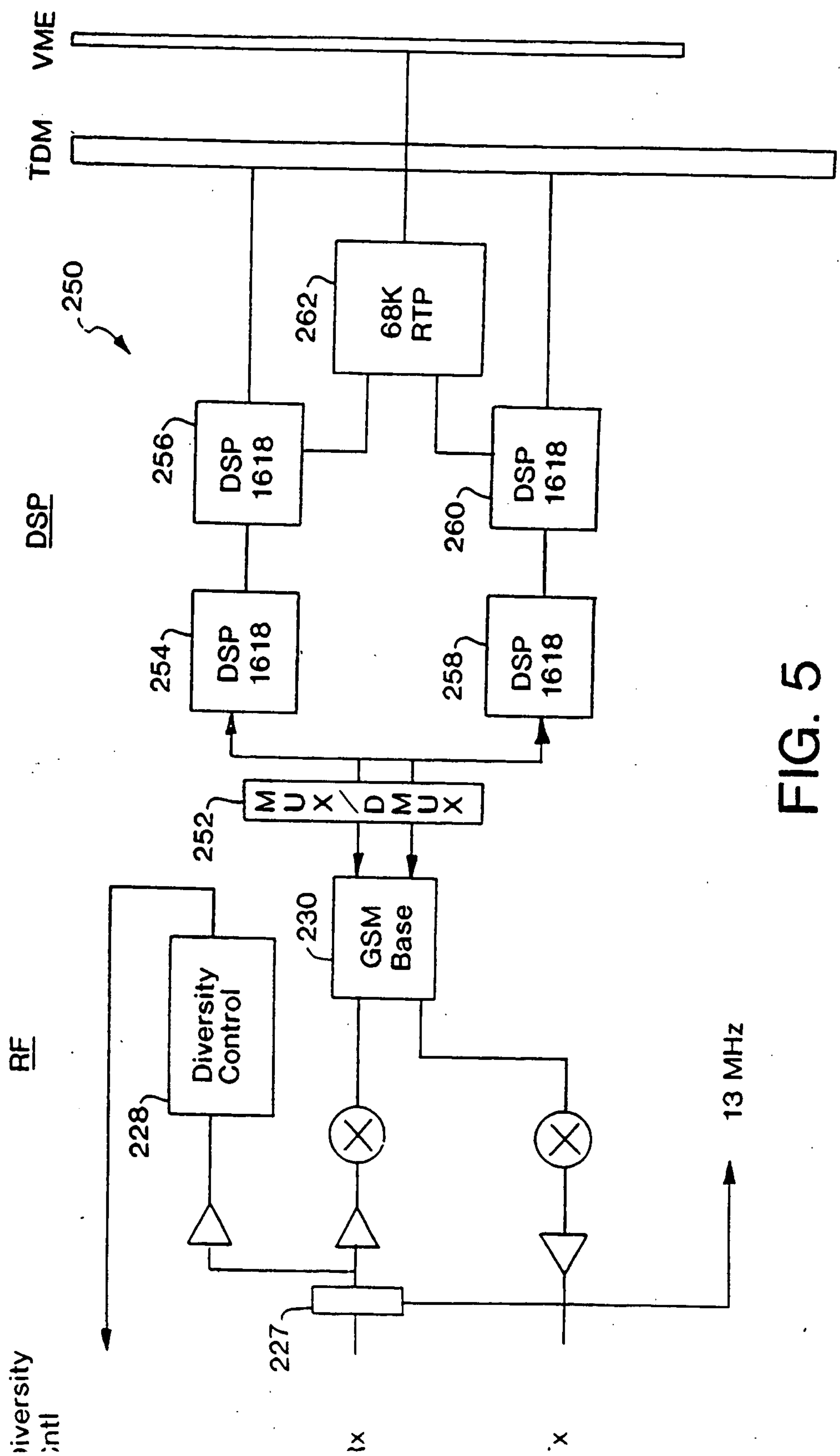

VME
TDM
250
262
68K RTP
DSP
256
DSP 1618
260
DSP 1618
254
DSP 1618
258
DSP 1618
252
MUX/DMUX
230
GSM Base
RF
228
Diversity Control
13 MHz
227

FIG. 5

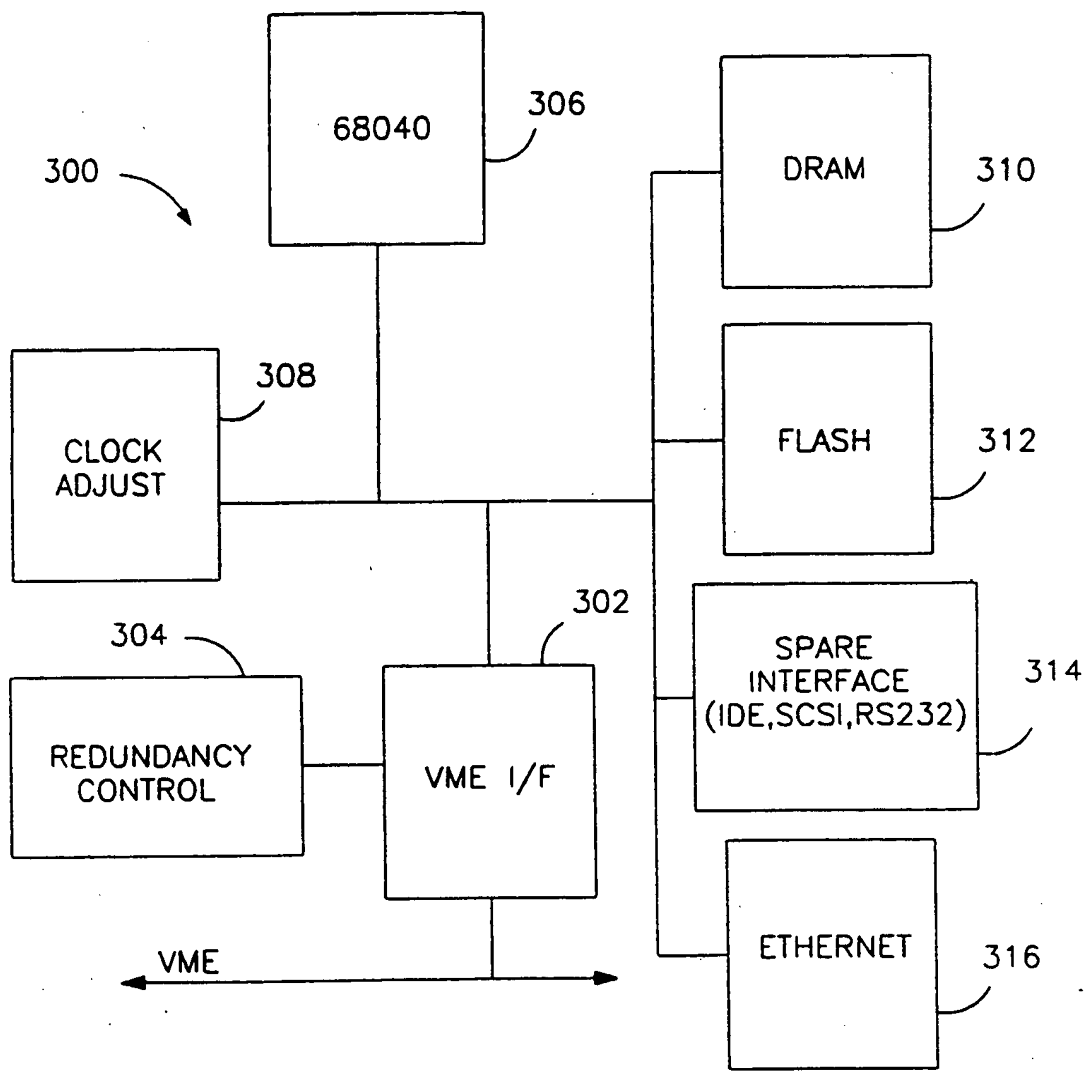

300
68040
306
DRAM
310
CLOCK ADJUST
308
FLASH
312
302
304
SPARE INTERFACE (IDE,SCSI,RS232)
314
REDUNDANCY CONTROL
VME I/F
ETHERNET
316
VME

FIG. 6

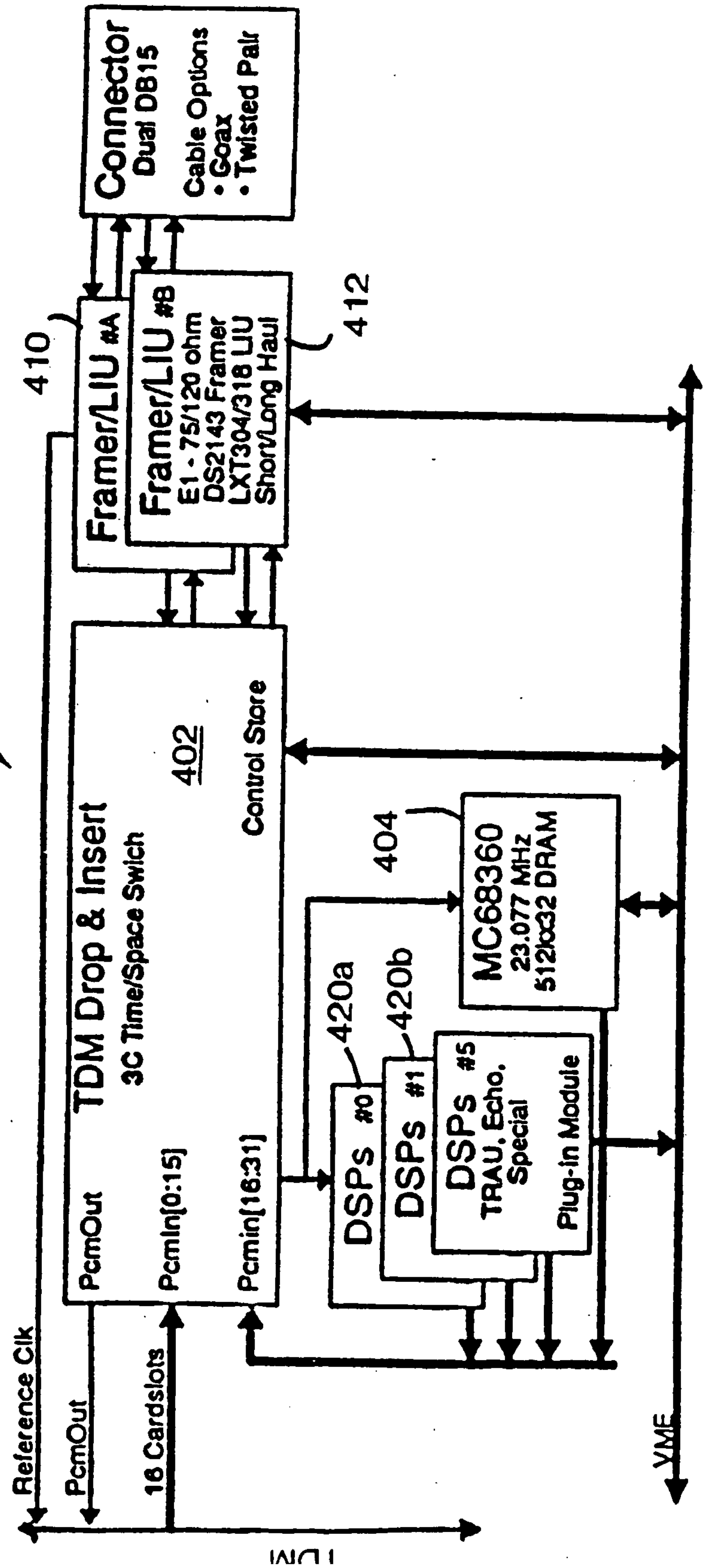

400
Connector
Dual DB15
Cable Options
• Coax
• Twisted Pair
410
Framer/LIU #A
412
Framer/LIU #B
E1 - 75/120 ohm
DS2143 Framer
LXT304/318 LIU
Short/Long Haul
TDM Drop & Insert
3C Time/Space Switch
402
Control Store
PcmOut
PcmIn[0:15]
PcmIn[16:31]
404
MC68360
23.077 MHz
512kx32 DRAM
420a
420b
DSPs #0
DSPs #1
DSPs #5
TRAU, Echo,
Special
Plug-in Module
Reference Clk
PcmOut
16 Cardslots
VME
TDM

FIG. 7

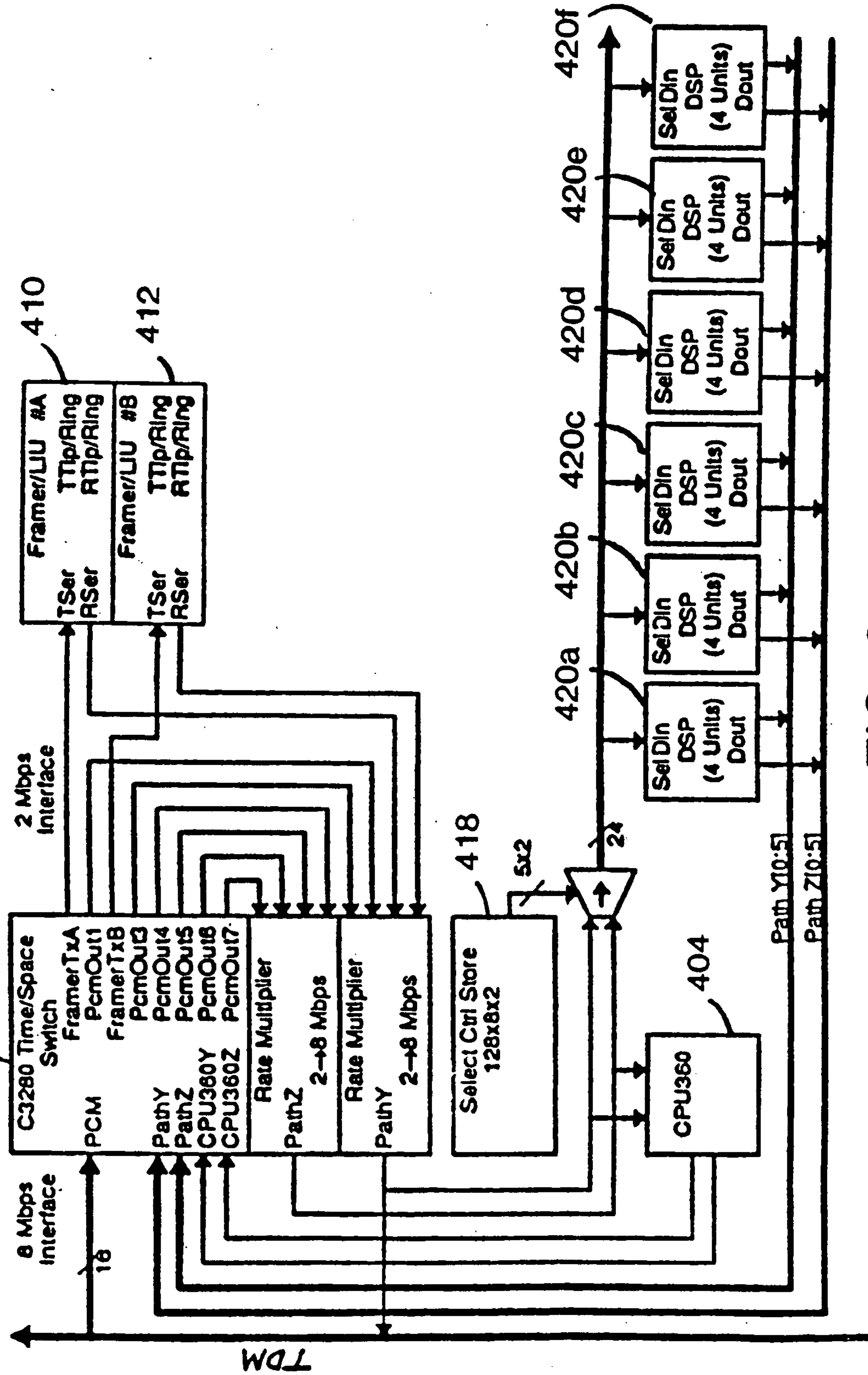

402
C3280 Time/Space Switch
FramerTxA
PcmOut1
FramerTxB
PcmOut3
PcmOut4
PcmOut5
PcmOut6
PcmOut7
PCM
PathY
PathZ
CPU360Y
CPU360Z
Rate Multiplier
PathZ
2→8 Mbps
Rate Multiplier
PathY
2→8 Mbps
2 Mbps Interface
8 Mbps Interface
18
TDM
410
Framer/LIU #A
TSer
RSer
TTip/Ring
RTip/Ring
412
Framer/LIU #B
TSer
RSer
TTip/Ring
RTip/Ring
418
Select Ctrl Store 128x8x2
5x2
24
404
CPU360
Path Y[0:5]
Path Z[0:5]
420a
420b
420c
420d
420e
420f
Sel Din
DSP
(4 Units)
Dout

FIG. 8

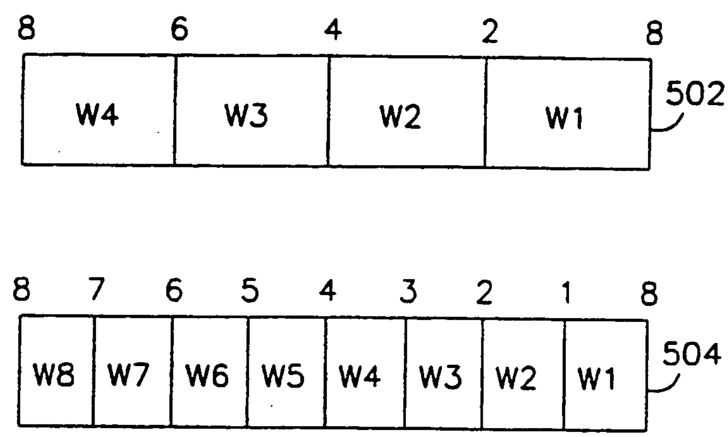

8
6
4
2
8
W4
W3
W2
W1
502
8
7
6
5
4
3
2
1
8
W8
W7
W6
W5
W4
W3
W2
W1
504

FIG. 9A

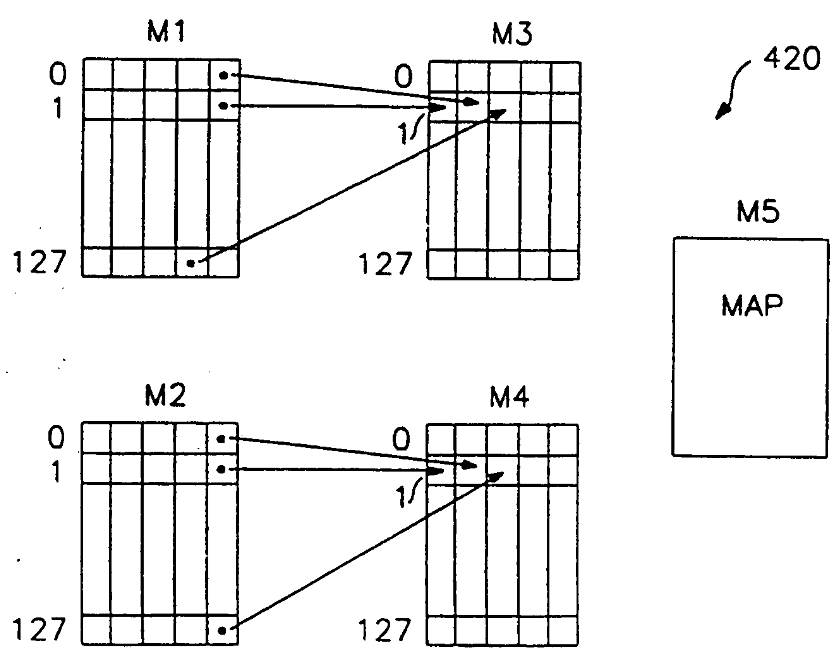

M1
M3
420
0
1
127
0
1
127
M5
MAP
M2
M4
0
1
127
0
1
127

FIG. 9B

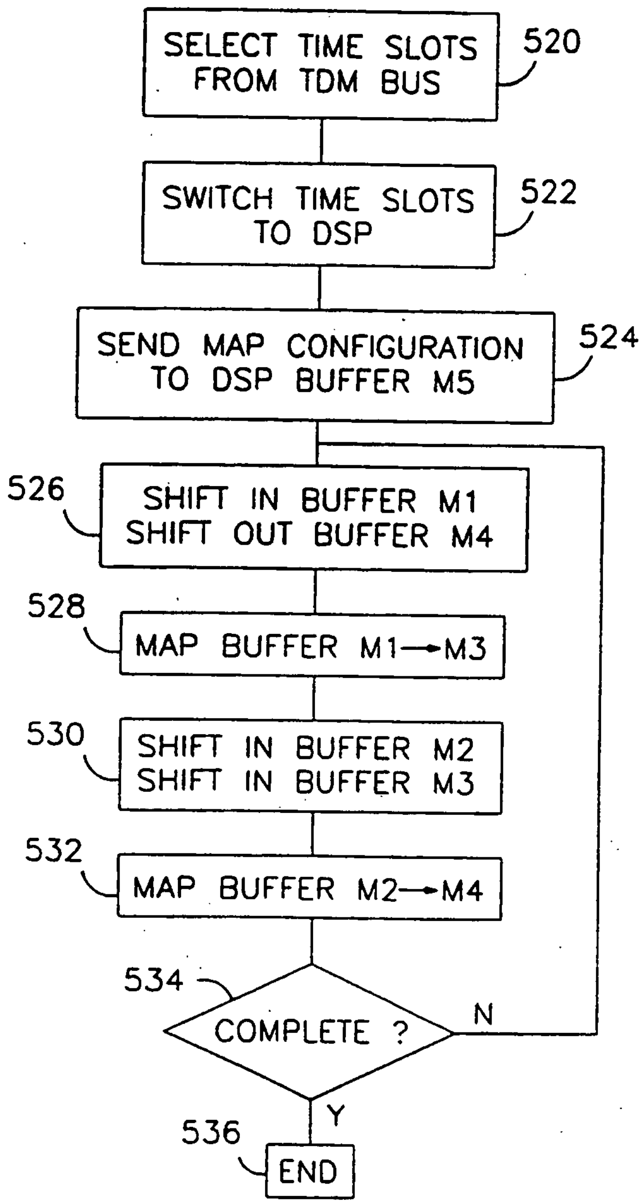

SELECT TIME SLOTS FROM TDM BUS
520
SWITCH TIME SLOTS TO DSP
522
SEND MAP CONFIGURATION TO DSP BUFFER M5
524
526
SHIFT IN BUFFER M1
SHIFT OUT BUFFER M4
528
MAP BUFFER M1→M3
530
SHIFT IN BUFFER M2
SHIFT IN BUFFER M3
532
MAP BUFFER M2→M4
534
COMPLETE ?
N
Y
536
END

FIG. 9C.

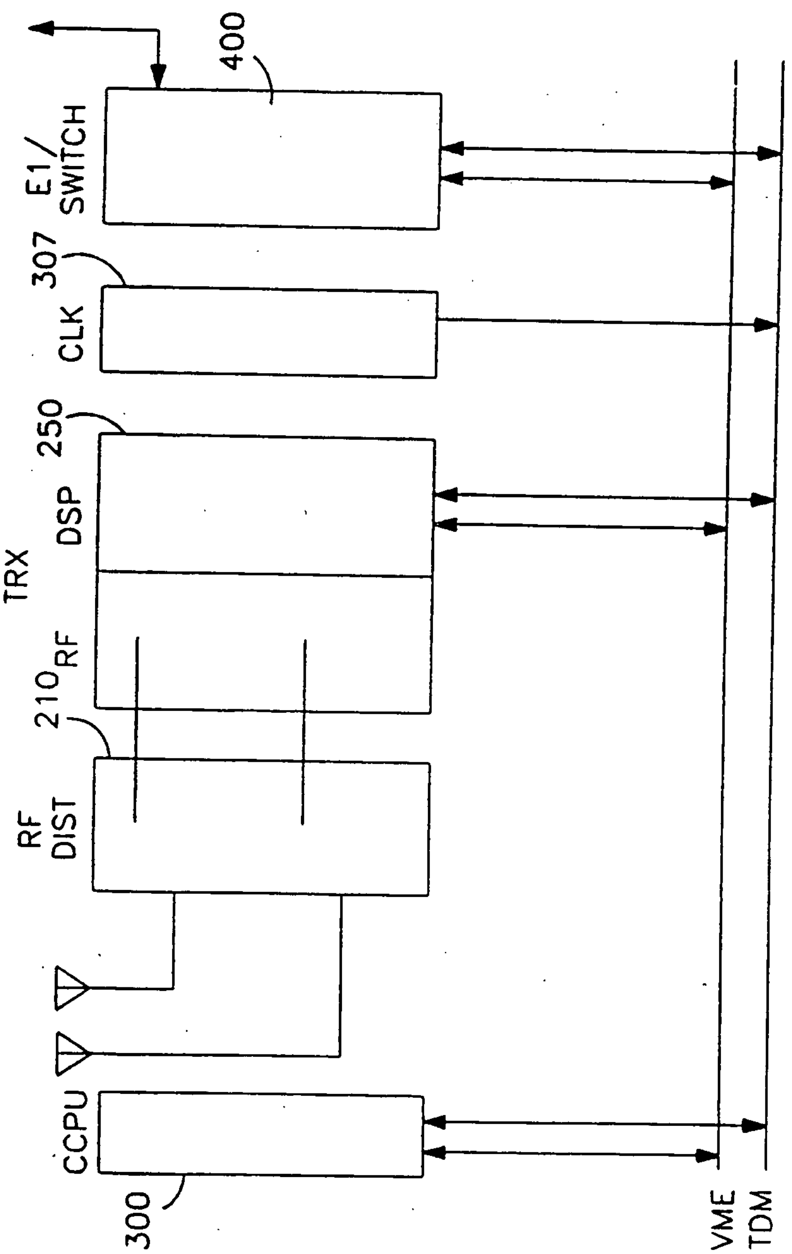
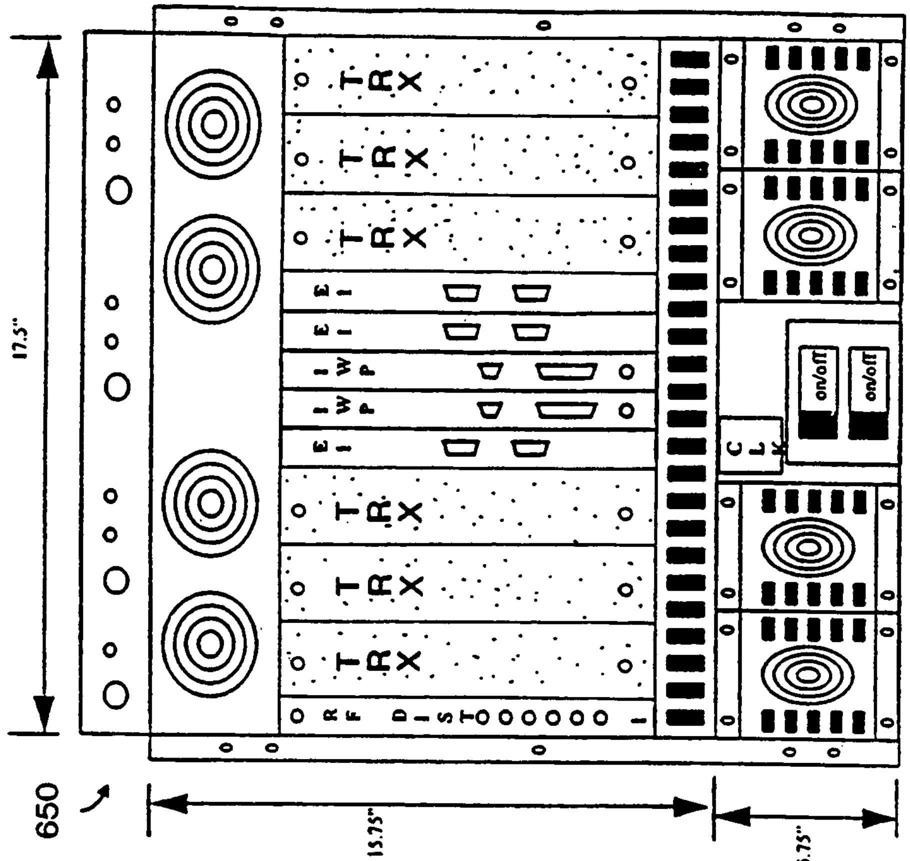
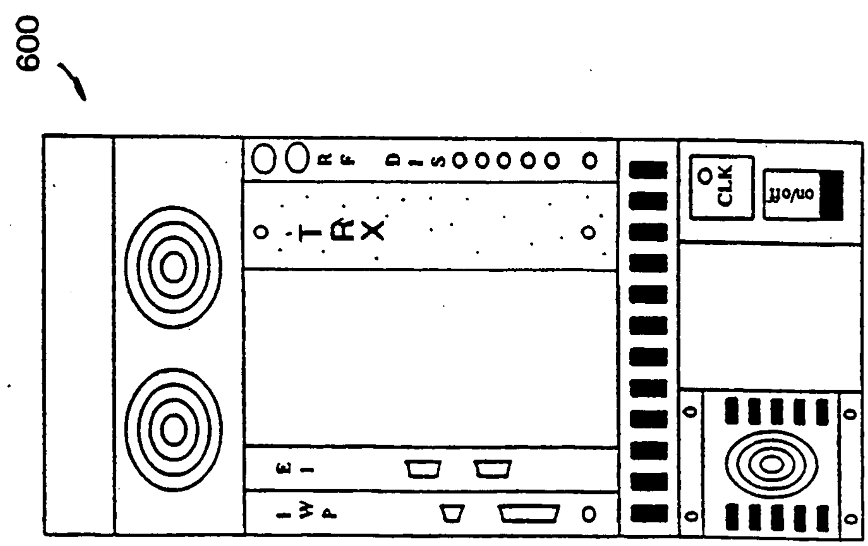

E1/
SWITCH
400
307
CLK
250
DSP
TRX
210
RF
RF
DIST
CCPU
300
VME
TDM

FIG. 10



650
17.5"
15.75"
5.75"
TRX
TRX
TRX
EI
EI
IWP
IWP
EI
TRX
TRX
TRX
RF DIST
CLK
on/off
on/off

FIG. 12



600
RF DIS
TRX
EI
IWP
CLK
on/off

FIG. 11

1 TRX BTS	BTS	BSC	BTS/BSC	MSC	BSC/MSC	BTS/BSC/MSC
1 TRX	3 TRX	0 TRX	2 TRX	0 TRX	0 TRX	2 TRX
1 TM	1 TM	6 TM	2 TM	6 TM	6 TM	2 TM
0 CCPU	1 CCPU	3 CCPU	2 CCPU	3 CCPU	3 CCPU	2 CCPU
1 Clk	1 Clk	1 Clk	1 Clk	1 Clk	1 Clk	1 Clk
0 RF Dist	1 RF Dist		1 RF Dist			1 RF Dist

FIG. 13

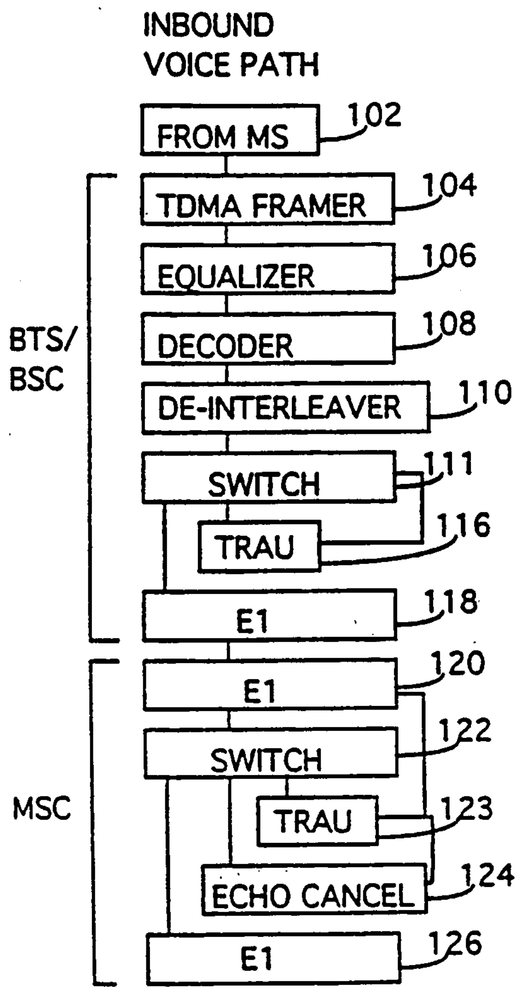


FIG. 14A

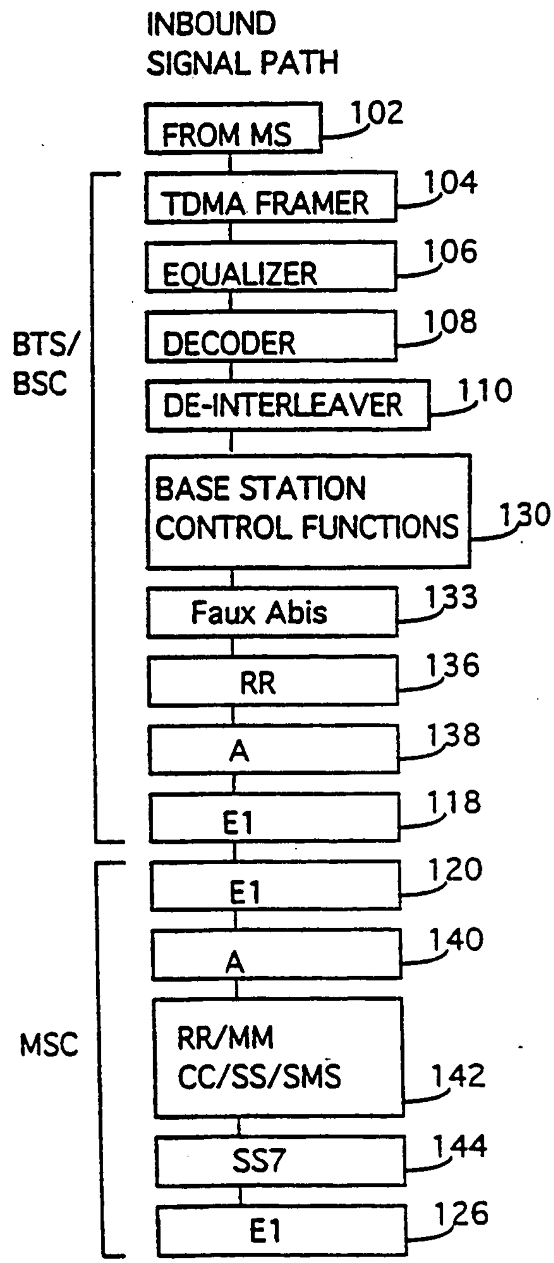


FIG. 14B

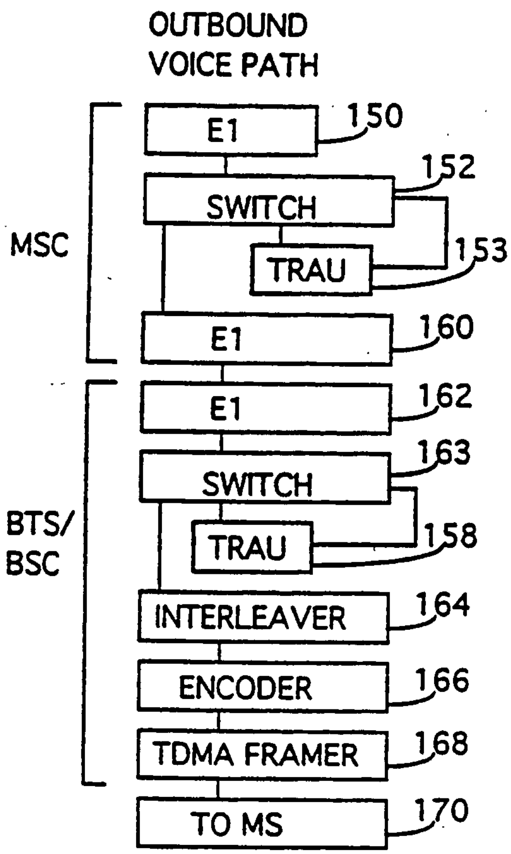


FIG. 14C

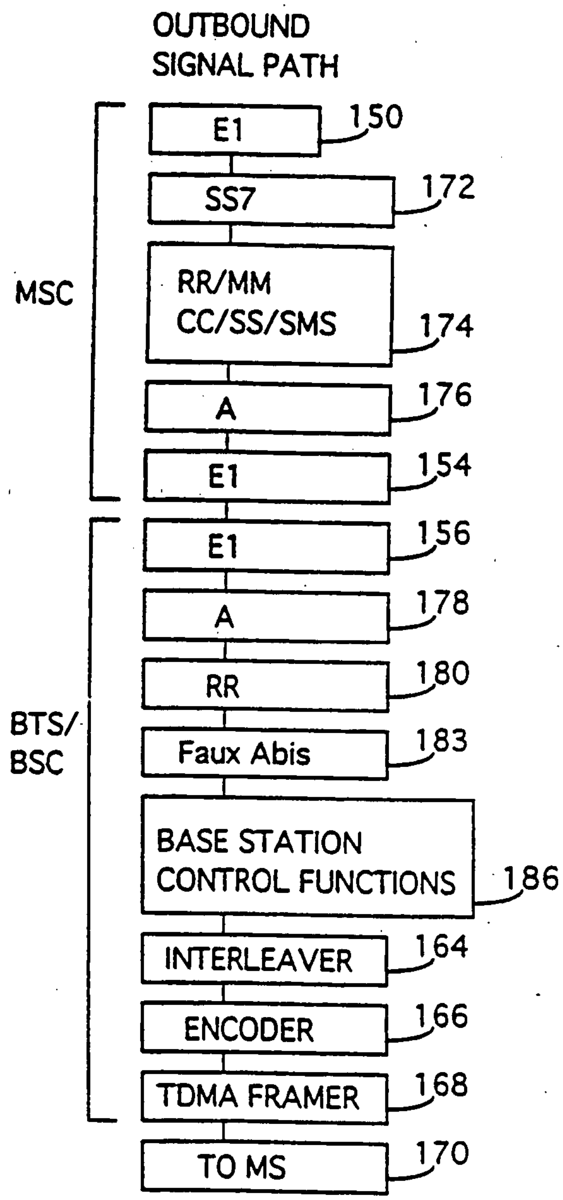


FIG. 14D

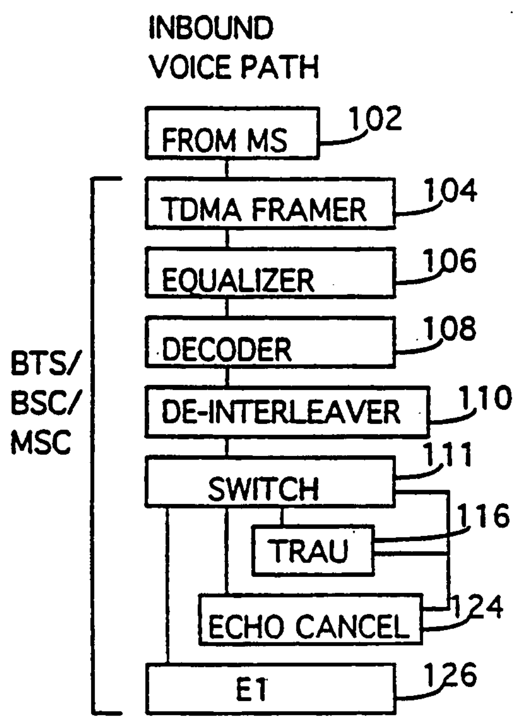


FIG. 15A

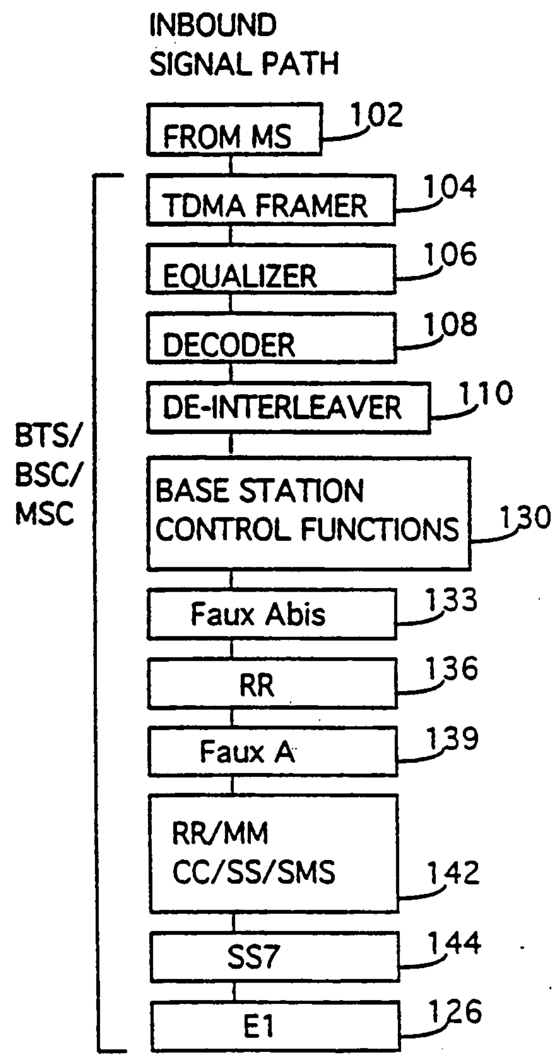


FIG. 15B

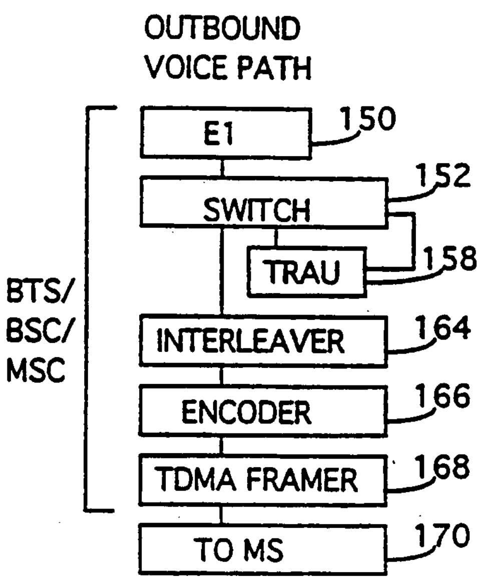


FIG. 15C

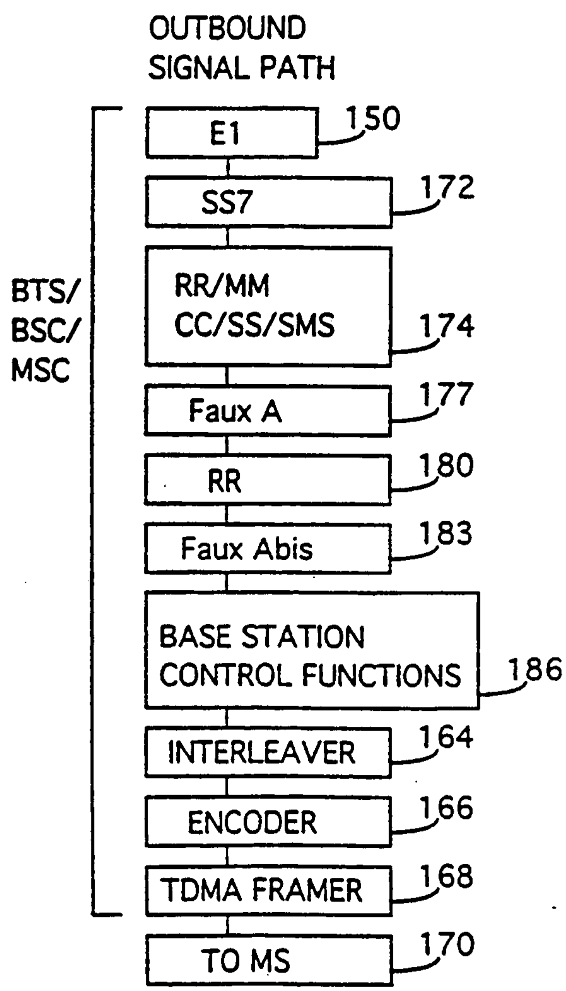


FIG. 15D

INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/US 96/05943

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04Q7/30

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04Q H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP,A,0 600 681 (ATT) 8 June 1994 see column 2, line 12 - column 5, line 10; figures 1-3 ---	1-20
X	EP,A,0 595 392 (PHILIPS ELECTRONICS) 4 May 1994 see claims 1-11 ---	1-20
X	EP,A,0 587 211 (PHILIPS ELECTRONICS) 16 March 1994 see column 4, line 37 - column 5, line 33; claim 1; figure 1 ---	1-20
X	EP,A,0 534 716 (NEC CORPORATION) 31 March 1993 see claims 1-3; figures 1-4 --- -/--	1-20

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

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Date of the actual completion of the international search	Date of mailing of the international search report
30 July 1996	27.08.96
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Authorized officer Bischof, J-L

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INTERNATIONAL SEARCH REPORT

Inter   nal Application No
PCT/US 96/05943

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP,A,0 526 285 (CABLE TELEVISION LABORATORIES) 3 February 1993 see abstract ---	1,5,10, 15-20
A	WO,A,91 00660 (MOTOROLA) 10 January 1991 see page 3, line 25 - page 4, line 13 -----	1,8,11

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

Intern al Application No
PCT/US 96/05943

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		CA-A- 2109788	31-05-94
		JP-A- 6233345	19-08-94
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		US-A- 5418838	23-05-95
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		JP-A- 6178347	24-06-94
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		AU-B- 5952290	17-01-91
		CA-A- 2063421	27-12-90
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		IL-A- 94773	11-11-94
		JP-T- 4505994	15-10-92
		KR-B- 9407670	22-08-94